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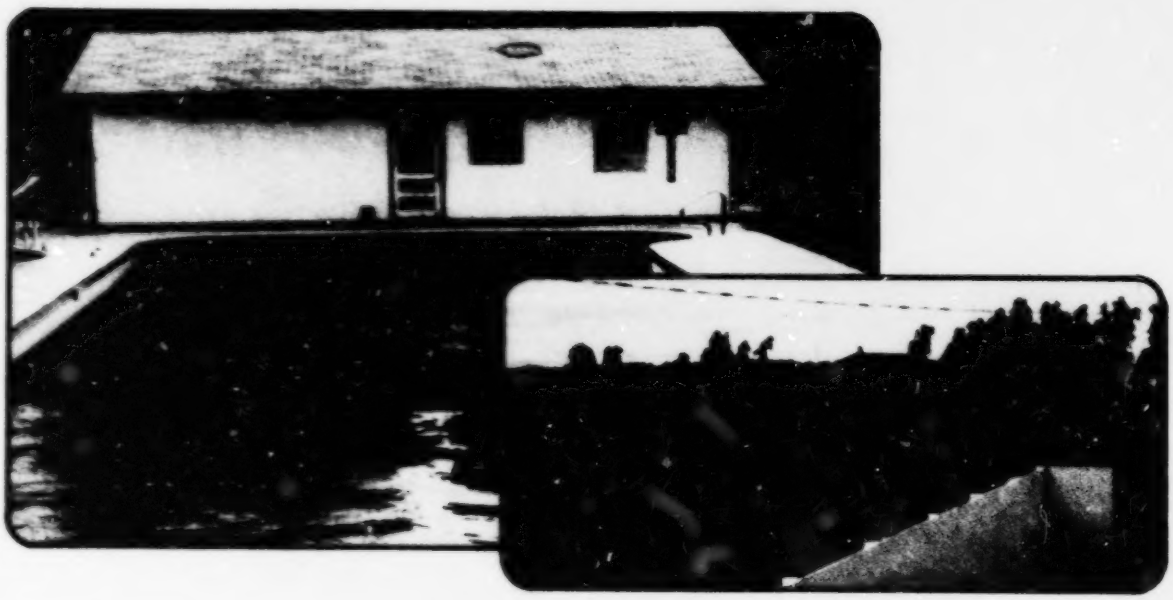

SOLAR HEATED SWIMMING POOL

VASSAR, MANITOBA

MG-12258

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MANITOBA/CANADA CONSERVATION

AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end the governments of Manitoba and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminates March 31, 1984. The Agreement is dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program has a total budget of $18 million.

The objectives of CREDA are:

* To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.

* To develop broad public awareness of the potential of renewable energy and conservation technology.

* To provide opportunities for the commercial application of the technologies within Manitoba.

* To create economic spin-off benefits for manufacturing, industry and commerce.

* To create employment in new or existing energy-related industries.

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EXECUTIVE SUMMARY

An outdoor swimming pool exposed to the sun will absorb most of the solar radiation it encounters, and will gradually tend towards a temperature near ambient. Supplementary heating is required to raise the water temperature to a preferred level for comfortable swimming, and to reach that level in a reasonable period of time. At Vassar the preferred pool temperature is approximately 25°C, and supplementary heat has been required to maintain that temperature during the summer. Until 1982 the supplementary heat was supplied by a propane-fired boiler. Later that year a solar heating system was installed with assistance by the federal and provincial governments. In 1983, the first full season of operation, the performance of the solar heating system was monitored.

Appin Solar Associates Inc. monitored the project on behalf of Manitoba Energy and Mines, under the Canada/Manitoba Conservation and Renewable Energy Demonstration Program (CREDA), and prepared this report. The report indicates that the solar equipment maintained satisfactory pool temperatures during most of the summer and the insulated pool cover significantly reduced overnight heat loss from the pool.

Based on the performance of the equipment, it is estimated that the pool cover has a simple pay-back period of 1.5 years, whereas the pay-back for the solar collectors is over 13 years. The simple pay-back period on the capital installation as a whole is estimated to be 6.3 years.

RESUME ADMINISTRATIF

Une piscine exterieure exposee au soleil en absorbe presque tous les rayons incidents et sa temperature tend a s'elever graduellement vers celle du milieu ambiant. Si l'on desire elever la temperature de l'eau davantage afin d'assurer le plus grant confort des baigneurs, et ce dans un delai raisonnable, il faut avoir recours a un systeme de chauffage supplementaire. A Vassar, la temperaturee preferee est d'environ 25°C et pour la maintenir pendant les mois d'ete il a fallu utiliser une source de chaleur supplementaire. Jusqu'en 1982, cette source a ete une chaudiere chauffee au gaz propane. Au cours de cette meme annee, un systeme de chauffage solaire a ete installe avec l'aide des gouvernements federal et provincial. Le rendement du noiveau systeme de chauffage a fait l'object d'un controle suivi pendant sa premiere pleine saison de fonctionnement en 1983.

La societe Appin Solar Associates Inc. a effectue le controle du systeme pour le compte du ministere de l'Energie et des Mines du Manitoba, dans le cadre du programme Canada-Manitoba de demonstration des energies renouvelables et des economies d'energie, et elle a redige le present rapport. Ce dernier revele que l'equipement solaire a maintenu la temperature de la piscine au degre voulu durant presque tour le'ete, tandis que la couverture isolante reduisait considerablement les pertes de chaleur pendant la nuit.

Compte tenu du rendement de ce materiel, on prevoit des periodes de recuperation simple de un an et demi pour la couverture de piscine et de 13 ans pour les collecteurs de rayonnement solaire. La periode de recuperation simple des depenses en immobilisation globales sera vraisemblablement de 6, 3 ans.

INTRODUCTION

The rapid rise in the price of oil since 1973 triggered a world-wide search for less costly alternative energy sources. Solar appeared to be one of the most promising sources. In 1978, the Canadian Government supported the development of solar energy equipment in Canada. Subsequent projects indicated that heating outdoor swimming pools in summer is one of the most effective applications.

For this particular application the solar collectors are not tilted at a steep angle since the sun is high in the sky during the summer, and it is rarely necessary to raise the water temperature more than about 10°C. Moreover, the pool water itself acts as a substantial thermal reservoir, and its temperature varies little from one day to the next. A collector area about half that of the pool surface is usually considered adequate, provided that a pool blanket is used to reduce losses.

The town of Vassar (pop. 134) is situated at the southern end of Sandilands Provincial Forest in southeast Manitoba, approximately 145 km from Winnipeg. To celebrate the Manitoba Centennial in 1970, the town built a 364,000 litre swimming pool. Prior to 1982 the pool was heated with propane. In 1982 a solar heating system was installed and began operation in August. The Chamber of Commerce received a grant of $4,000 from the Canada/Manitoba Conservation and Renewable Energy Demonstration Program (CREDA) towards the total installed cost of $11,339.

The equipment installed included solar collectors and an insulated cover which is unrolled over the pool each night. This project directly addressed two of the three requirements of CREDA - the use of renewable energy as obtained from the collector, and energy conservation, the function of the insulated cover.

As an essential part of the CREDA project, Appin Solar Associates, Inc. was commissioned to monitor and evaluate the performance of the solar equipment during its first full year of operation, and to determine the energy saved.

PROJECT OBJECTIVES

1. To record the daily, weekly and monthly pool temperature profiles for the solar heated Vassar Community Swimming Pool during the first season of operation of the solar collector.

2. To record the corresponding ambient air temperature so that the pool performance can be related to the average climatological conditions in Manitoba.

3. To compare the performance of the system with and without a swimming pool cover.

4. To estimate pool heat loss data and associated solar system design criteria for community sized outdoor swimming pools in Manitoba.

DESCRIPTION OF SYSTEM (See Figs. 1 to 4)

The solar collectors, manufactured by Petro-Sun International of Quebec and supplied by Nordstrom Enterprises of Sprague, Manitoba, are of ultraviolet-stabilized black polypropylene and polyethylene, arranged in two banks of twelve panels, each 1.22 m x 3.05 m, giving a total collector area (89 m^2) about half that of the pool surface. When the panels are in circuit, water from the pool is pumped through filters and into a manifold pipe at the bottom of each of the heater banks. It then rises through the heaters to a header manifold pipe from which it is returned to the pool. See Fig. 5.

The solar array, which is situated slightly to the north-west of the pool, is mounted on a structure 3 m above the ground, oriented towards the south, and tilted at an angle of 30° to the horizontal. This angle is about optimum for the collection of summer solar radiation in southern Manitoba*.

A small pump-house at the north end of the pool contains three filters, each with its own pump, two thermally controlled by-pass valves, one in each solar circuit, and the propane heater, which is supplied from a 4,500 litre tank. The solar equipment includes a lightweight insulated plastic pool cover to reduce heat losses from the pool overnight. Thus the complete solar installation consists of the solar collectors and their supporting structure, the by-pass valves and the insulated pool cover.

In operation, the pumps circulate the pool water through the filters, and water from two of the filters flows in two parallel loops through the solar panels, while the third filter returns water to the pool via the propane heater.

* The optimum angle for the collection of summer solar radiation is usually considered to be latitude minus 15°, which in the case of Vassar would be 34°.

When the sensors detect an adequate level of solar radiation the thermally-controlled by-pass valves actuate to direct the circulating water through the solar panels (see Fig. 5), where it is heated before returning to the pool. The valves are designed to close if the water flowing from the panels exceeds a pre-set temperature. They also close when there is insufficient solar heat*. This is to prevent the heat in the pool water from being lost by radiation from the panels during the night.

A thermostat in the propane heater brings it into operation when pool water circulating through it drops to a pre-set level - about 23°C. The propane heater cuts out again at approximately 25°C.

The insulated cover is unrolled over the pool each night, thus reducing heat losses by conduction, radiation and evaporation from the pool itself.

* The performance of the by-pass valves does not appear to have been entirely satisfactory. The by-pass valves sustained damage believed due to lightning during 1982 and were not back in operation until July 1983. The pool operated from then until August 10, when the valves failed again.

It is important for the correct operation of the solar system that pool water should not flow through a solar array at night. Just as it performs as an efficient collector of solar heat during the day, so can it lose heat as an efficient radiator at night, if pool water continues to circulate through it.

MONITORING PROCEDURE

For the purpose of recording temperatures a Fluke 10 channel Data Logger (Model No. 2240C) was made available by Manitoba Reseach Council. It was installed on June 18 in the pool pump house. Iron constantan (type J) thermocouples were attached to the piping (and wrapped with insulating material to isolate them from ambient temperatures) to sense temperatures of the following:

- water leaving the solar array,
- well water delivery pipe,
- water leaving the propane heater,
- water leaving the pool.

Another thermocouple mounted in the shade on the north side of the pump house sensed ambient temperatures.

The data logger was programmed to print out all the temperatures at intervals of two hours.

Data was collected from June 18 until the pool was closed for the season on September 6. The data was then transferred to a computer and after preliminary analysis was reproduced on a graphic plotter.

PERFORMANCE

The information presented in this section is shown graphically in figure 6. The lower diagram is derived from the temperature data recorded as part of this project, while the upper diagram is based on the solar radiation records collected by Environment Canada at Winnipeg International Airport. The lightly shaded envelope embraces the variation in daily ambient temperatures, while the narrower darker envelope shows the range of the temperature of the water in the pool. The symbol O shows when the propane heater was operating. High points on the upper diagram indicate clear sunny days, low points suggest overcast.

Filling of the pool began during the weekend June 9/10, and by June 15 it was at capacity. Since the temperature of the well water used to fill the pool ranged between 10°C and 12°C, and since the weather at that time was cloudy, with mostly below normal temperatures, the propane heater was used to bring the pool up to temperature as quickly as possible.

The Fluke Data Logger was installed on Saturday, June 18, when the pool temperature was raised to 22°C. The propane heater operated intermittently on its thermostat for short periods over the next few days, but by June 22 the weather was warm and sunny, and over the next week the solar heaters maintained the temperature between 22°C and 26°C.

The weather changed again in the last few days of June, temperatures dropped below normal and days were cloudy. The pool temperature fell steadily from a high of 26°C on June 28 to a low of 19°C on July 5. (That night the ambient temperature dropped to 4°C). At this time the propane heater started up again. It operated for some hours that day and raised the pool temperature to 23°C before shutting down.

A long hot spell followed (Environment Canada noted that in Winnipeg July was the warmest on record since 1957), which brought the pool temperature up to around 30°C (a peak of 31.7°C was recorded) by July 14. For the duration of the month the pool temperature cycled between 26° and 29°, with an overnight drop of about 2° and a rise during the day of 2° - 3°.

During the first ten days of August (also the warmest August on record in Winnipeg, according to Environment Canada) the solar heaters continued to maintain the pool temperature between 26°C and 30°C, but in the early morning of August 9 the ambient temperature dropped to 9°C and the pool temperature fell to 23°C.

It recovered again, and stayed mostly above 25°C until August 20 when, during a spell of cool cloudy weather the pool temperature fell to 23°C. The propane heater cut in by 2:00 p.m. that day and ran until close to midnight. It also operated during the following night until the pool temperature exceeded 25°C. Then the weather improved again and the water temperature began to climb slowly. It stayed above 25°C until the first few days of September, but the weather changed on September 5, and the pool temperature began to decline. The pool was closed for the season on September 6.

Note:

Although July and August were record warm months, solar radiation as measured at Winnipeg International Airport was marginally below normal in July. The August figure was 8% above normal.

EFFECT OF INSULATED COVER

In order to minimize heat loss, the insulated pool cover was placed on the pool each night throughout the season, except for two occasions when the cover was purposely left off to monitor the effect. Throughout the season, the average overnight drop in pool temperature was less than 2 Celsius degrees.

The first time the pool was left uncovered, the night of Friday, July 8, was during a spell of fine weather. The night was mild, but with gusty winds, and the ambient pool temperature dropped by more than 4 Celsius degrees. The pool was left uncovered also during the weekend August 20-21. However, the ambient temperatures on the 19th had been below normal, with moderate winds, and the air temperature dropped overnight to 6.5°C. The pool temperature, which had not reached as high as 26°C that day, dropped to 23°C at 4 a.m. next morning, at which point the propane heater cut in. It operated during the afternoon and evening of August 20 and again in the latter part of the next day. The effect of uncovering the pool that weekend was therefore masked by the performance of the propane heater, and instead of the pool temperature falling it was pulled back to 25°C.

Thus the attempt to compare pool performance with and without the pool cover has yielded only limited results. The cooling effect of the gusty winds on the night of July 8 was probably responsible for the temperature drop.

On the night of August 9 the pool temperature fell by more than 5 Celsius degrees, but, as was indicated by the thermocouple on the well water delivery pipe, the make-up water had been left running that night. The addition of so much cold water would account for part of the excessive temperature drop.

ANALYSIS

As discussed in the previous section, the pool was left uncovered on only two occasions during the 1983 season, and under the circumstances described it is difficult to draw precise conclusions from the results. The drop in the temperature of the uncovered pool on the night of July 8 - more than 4 Celsius degrees was more than twice the average nightly temperature drop throughout the season. This may not be typical, but even if the use of the pool cover did no more than reduce the overnight drop in temperature by one Celsius degree, the energy saved over the season would still amount to 122 Gigajoules (GJ)*.

The efficiency of the solar collectors is a function of water flow and of the difference between water temperature and the temperature of the surrounding air. Assuming that they operate at an average efficiency to 50%, then over the 80-day season they will contribute a further 80 GJ*, so that the pool cover and the solar collectors will together account for 122 + 80 = 202 GJ.

The average annual propane consumption at the Vassar pool from 1979 to 1981 was 8900 litres, and assuming an efficiency of 70% for the propane heater, this would provide 169 GJ of heat in the pool water. Of the 169 GJ, 23 GJ would be required to raise the water to temperature at the beginning of the season, leaving 146 GJ to maintain the temperature at 25°C over the pool season.

On the basis of the above assumptions, the solar equipment can more than match the amount of heat energy needed to maintain the pool temperature over the summer season. The chart of pool performance (Fig. 6) shows that the pool temperature stayed well above 25°C on 40 of the 80 days of the season, confirming that surplus heat was available.

* See Appendix II.

DAILY HEAT BALANCE

Losses

The drop in pool temperature each night from June to September averaged 1.7 Celsius degrees, and to maintain the desired temperature an equivalent amount of heat had to be recovered during the day. In addition to raising the temperature of the water in the pool, extra heat was required to warm up the make-up water. About 4 cm of water, or 7000 litres, was lost each day due to evaporation, and the make-up water was drawn from the well at a temperature of 10°C. The amount of heat required each day to recover the temperature lost during an average night, and to bring the make-up water to pool temperature, was

[(364000-7000) litres x 1.7° x 4184 J/kgcal + 7000 litres x 15° x 4184 J/kgcal] x 10^{-9} GJ/J = 2.98 GJ.

Gains

During June, the mean daily insolation on a horizontal surface in Winnipeg is 22.75 MJ/m^2 (see Appendix I). On a south-facing surface tilted at 30° it is 21.90 MJ/m^2. Figures for Vassar would be of the same order as for Winnipeg. The surface area of the pool is 174 m^2, and since water absorbs approximately 75% of the solar energy striking its surface, the mean daily direct heat gain by the Vassar pool in June would be

174 m^2 x 0.75 x 22.75 MJ/m^2 x 10^{-3} GJ/MJ = 2.97 GJ.

The solar collectors have a total area of 89 m^2 and are tilted at 30°. If we assume that they operate at an efficiency of 50%, then their mean daily heat gain in the month of June would be

89 m^2 x 0.5 x 21.90 MJ/m^2 x 10^{-3} GJ/MJ = 0.97 GJ.

Thus the total mean daily heat gain in June from both pool and collectors would be 2.97 + 0.97 = 3.94 GJ. For the month of July the mean daily heat gain would be 4.29 GJ and for August 3.65 GJ.

Thus, during the months of June, July and August in a normal year the direct solar radiation on the pool surface, plus the solar radiation collected by the solar array, should be adequate to maintain the pool temperature. This is provided that each night the pool cover is applied and the pool water is not circulated through the collectors.

ECONOMIC REVIEW

During the years 1979 to 1981 propane purchases for the pool averaged 8900 litres per season.

In 1983, propane was used at the beginning of the season to raise the pool temperature up to 25°C from 10°C, the temperature of the well water. Assuming an efficiency of 70% for the propane heater, it would require approximately 1200 litres of propane for this purpose. Raising the pool temperature from 19°C to 23°C, as the propane heater did on July 5, would have taken a further 320 litres, so it is estimated that approximately 1520 litres of propane had been used up until July 6, when the gauge on the propane tank indicated 65% full, or 2950 litres. By the end of the season the tank was 54% full, indicating 2450 litres, so over the season it is estimated that approximately 2000 litres of propane were consumed, or 22% of the average consumption for the three years before the solar collector was installed.

The total cost of the propane used (at 26¢/litre) was $520, representing an annual saving of $1,794. The total installed cost of the solar equipment was $11,339, of which $1,650 was the cost of the insulated pool cover and $9,689 the cost of the collectors and ancillary items. The analysis on page 10 concludes that the collectors and the pool cover account for 202 GJ over the pool season, and of that figure the cover accounts for 122 GJ or 60%.

Applying the same figure to the saving in propane the pool cover could then be credited with saving 0.60 x $1,794, or $1,076. At a cost of $1,650 this represents a simple pay back of 1.5 years.

The solar collectors are estimated to have accounted for 80 GJ, or 40% of the 202 GJ. 40% of $1,794 = $718, and at a cost of $9,689 this gives a simple pay back, on the collectors, of 13.5 years.

CONCLUSIONS

By the regular use of the insulated pool cover at night, the performance of the solar collectors, plus normal solar radiation on the pool surface, the pool temperature was kept above 23°C from July 6 to the end of the month. The pool temperature was higher by 4° at the end of the month than on the 6th.

During August, by use of the solar equipment, an adequate pool temperature was maintained on all but two days.

Throughout the season an estimated 2000 litres of propane were consumed, of which approximately 1200 litres were used to raise the pool fill-up water from well temperature to 25°C at the beginning of the season.

Use of the pool cover appears to contribute significantly to the maintenance of satisfactory pool temperatures. This simple energy conserving device should be a first consideration in any plan to take advantage of solar energy for swimming pool heating.

Additional economies in the use of propane could have been affected had the pool been filled a few weeks before the start of the season, and use made of the solar equipment to raise the water temperature. However, to obtain full advantage of the equipment would have required daily attention to replace and remove the pool cover and to check the operation of the solar collector by-pass valves.

The results show that, for an outdoor swimming pool operating during the summer in southern Manitoba, the combination of insulated pool cover plus solar collector offers a viable alternative to conventional heating systems.

ACKNOWLEDGEMENT

Thank you to Mr. Ovide Cote of Vassar for providing information on propane purchases, for re-setting the data logger following power interruptions, and for his general cooperation on this project.

APPENDIX I

Mean Solar Radiation (RF1) as measured on a horizontal surface at Winnipeg International Airport by Environment Canada -

June	22.75 MJ/m^2
July	22.99
August	18.92
September	13.31

Solar radiation falling on a south facing surface inclined at 30^o to the horizontal at the latitude of Winnipeg -

June	21.9 MJ/m^2
July	24.2
August	22.0
September	16.8

Calorific value of propane	27.1 MJ/litre
Vassar pool surface area	174 m^2
Solar collector surface area	89 m^2

APPENDIX II

Energy collected by Vassar pool solar array, assuming 50% efficiency.

June 89	m^2 x 21.90 MJ/m^2	x 13 days	x 0.5 x 10^{-3} =	12.67 GJ
July 89	x 24.20	x 31	x 0.5 x 10^{-3} =	33.38 GJ
Aug 89	x 22.00	x 31	x 0.5 x 10^{-3} =	30.35 GJ
Sept 89	x 16.80	x 5	x 0.5 x 10^{-3} =	3.74 GJ
				80.14 GJ

Energy conserved by the insulated pool cover during the 80-day summer season, assuming overnight pool temperature drop reduced by one Celsius degree -

364000 litres x 1 Celsius degree x 4184 J/kgcal x 80 days x 10^{-9} = 121.8 GJ

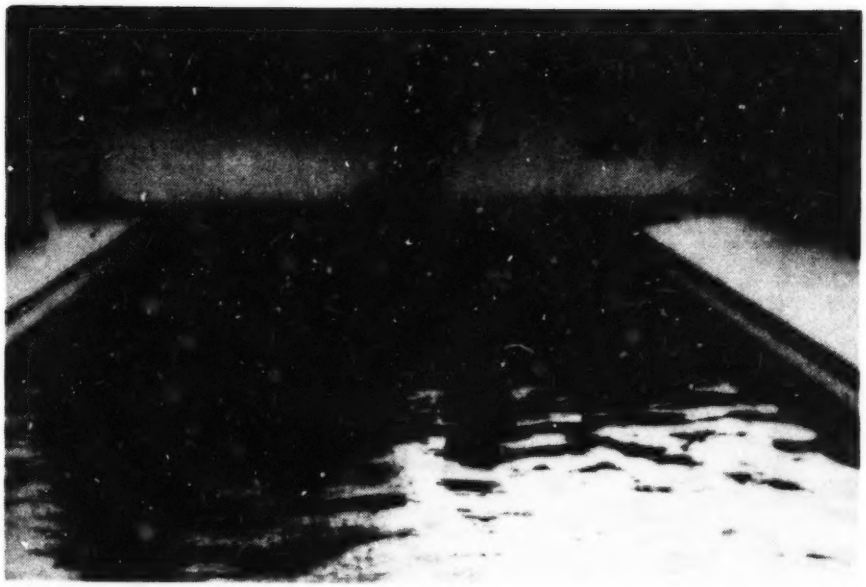


Fig. 1 The Vassar Pool

Fig. 2 The Solar Array

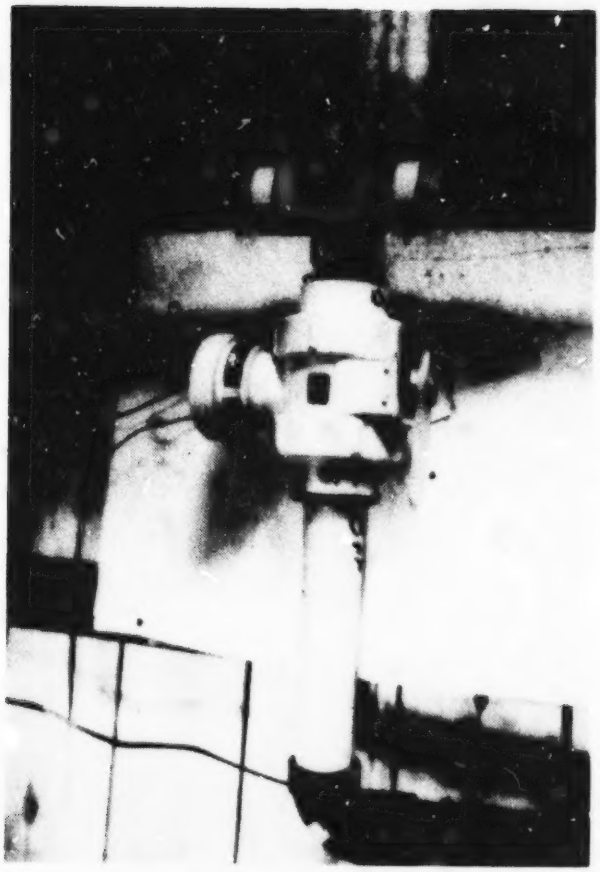


Fig. 3 By-Pass Valve

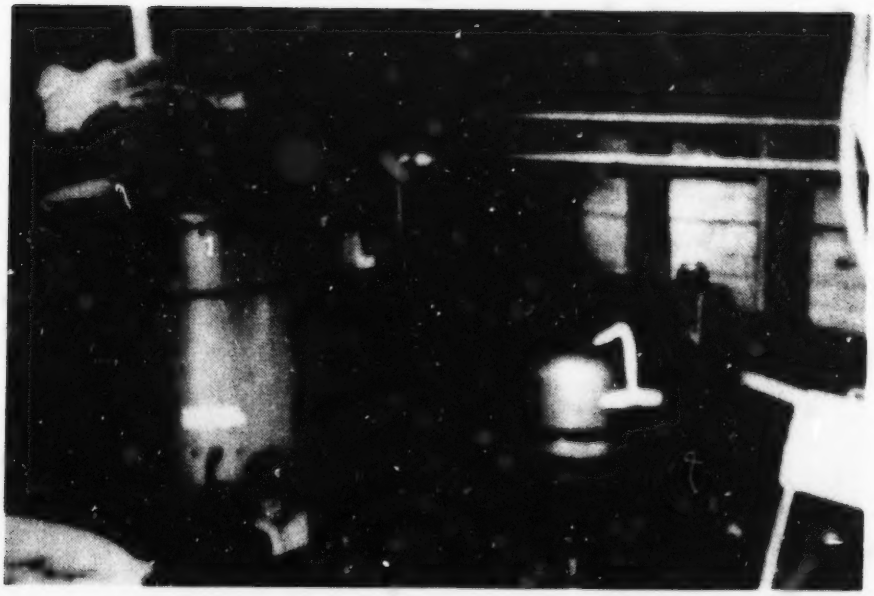
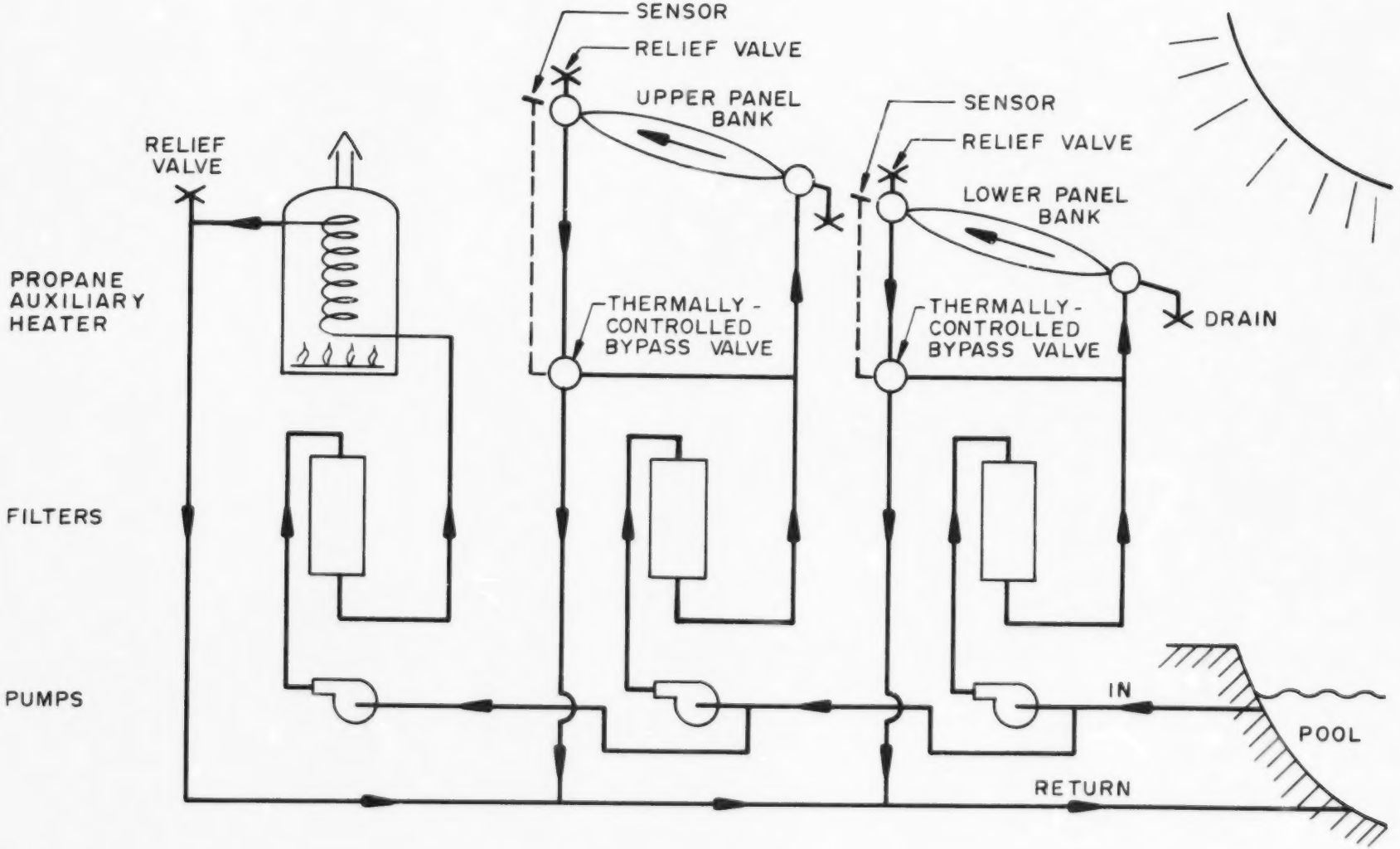


Fig. 4 Propane Heater and Filter



VASSAR SOLAR POOL HEATING SYSTEM

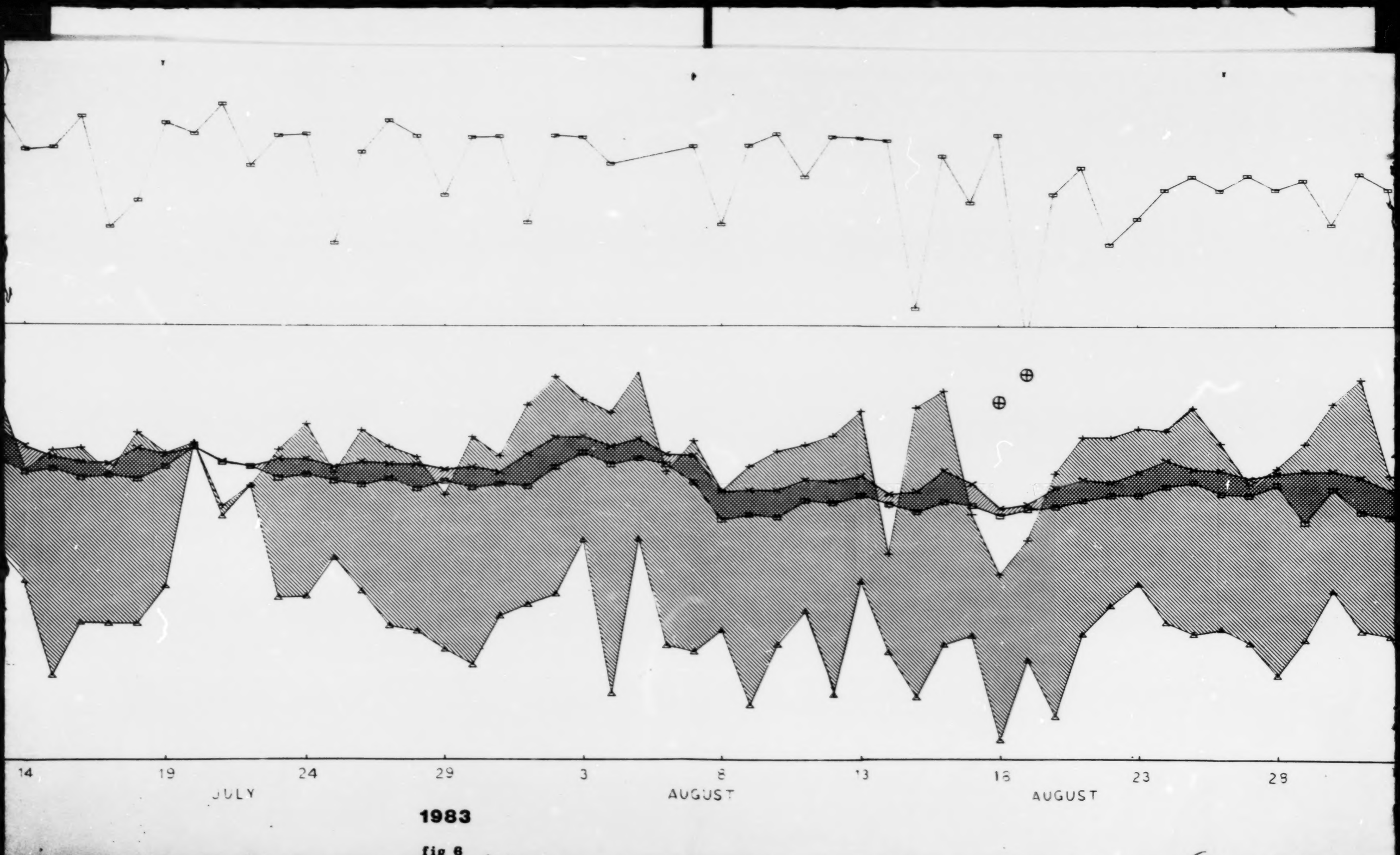
SOLAR RADIATION (RF1)
MJ/m²

TEMPERATURE
°C

35
30
25
20
15
10

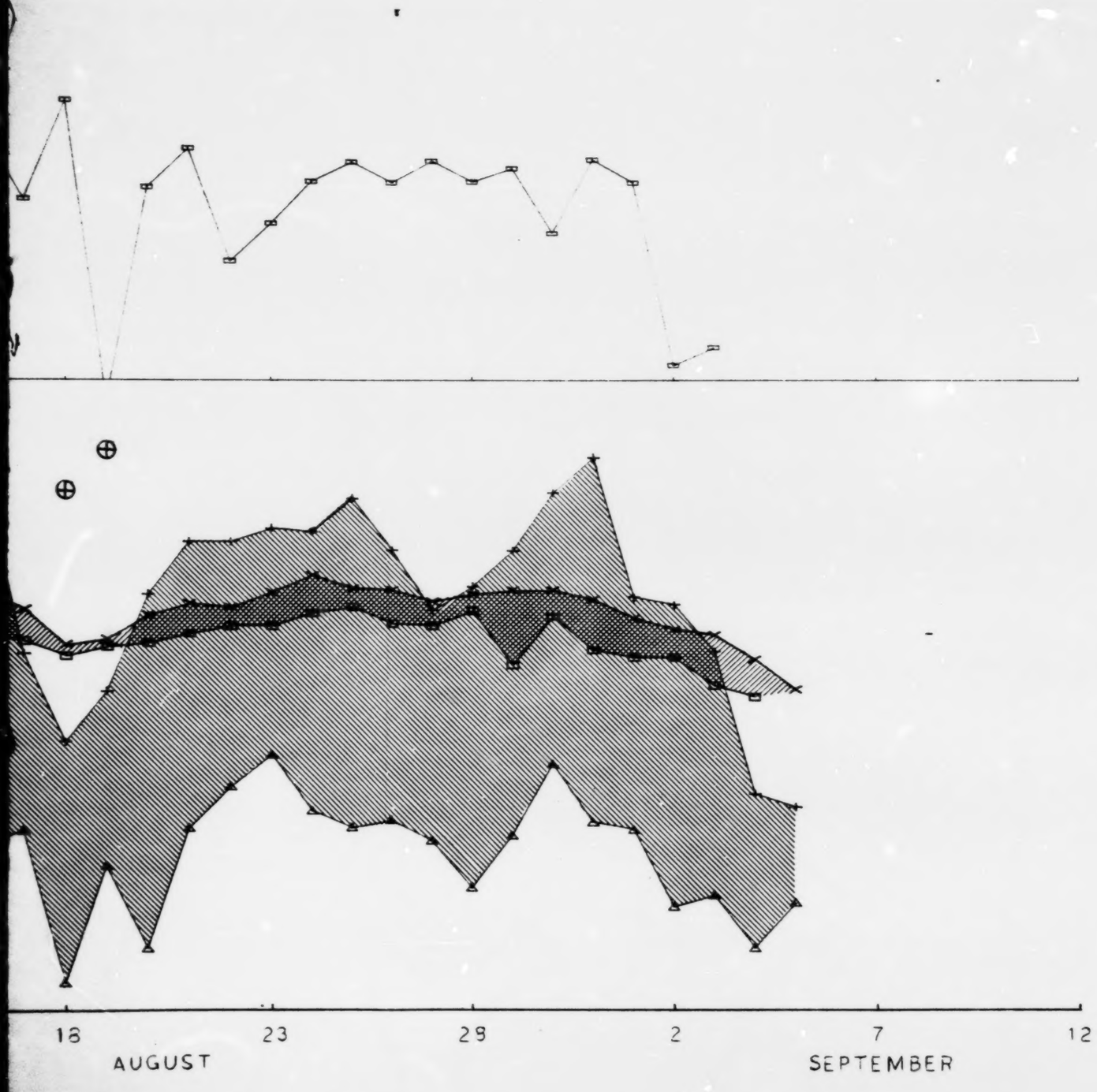
14 19 24 29 4 9 14 19 24

JUNE JULY JULY



1983

fig 6



LEGEND

AMBIENT AIR TEMPERATURE: max. +
min. △
POOL WATER TEMPERATURE; max. ×
min. □
PROPANE HEATER OPERATING; ⊕

NOTE: Solar Radiation (RF1) as Measured at Wpg. International Airport.

POOR

QUALITY

ORIGINAL